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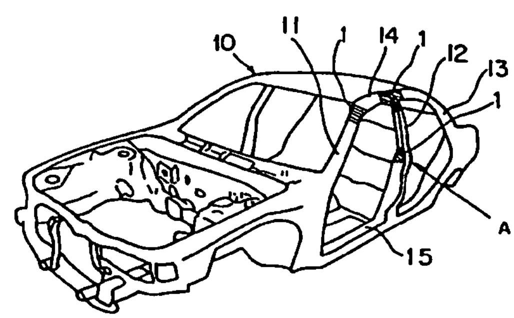
(54) HEAT-EXPANDABLE FILLING REINFORCEMENT AND CLOSED-SECTION STRUCTURAL-MEMBER STRUCTURE REINFORCED WITH SAID REINFORCEMENT

(57) This invention relates to a reinforced closed-section structural-member structure making use of a heat-foamable filling reinforcement. The structure has been formed by connecting plural closed-section structural members (11-15) together. These closed-section structural members (11-15) are internally filled with a heat-foamed filling reinforcement (1) which comprises an epoxy resin material, a synthetic rubber material and a thermoplastic resin material as components.

FIG. 1



SITES WITH FOAMED MATERIAL APPLIED THEREIN

EP 0 775 721 A1

Description

TECHNICAL FIELD

This invention relates to a heat-foamable filling reinforcement and also to a reinforced closed-section structural-member structure making use of the same.

BACKGROUND ART

Foamed materials are now used in pillars, roof header panels and the like of vehicle bodies, centering around high-grade vehicles, with a view to achieving improvements in noise insulation and improvements in energy absorption characteristics. It is FIG. 21 that illustrates sites with a foamed material applied therein. As is shown in FIG. 21, an foamed material 100 is filled in pillars (front pillars 11, center pillars 12 and rear pillars 13) of a vehicle body 10.

For the foamed material 100, a formed sheet material of a synthetic rubber such as a BR rubber (butadiene-base rubber) or an SBR rubber (styrene-butadiene-base rubber) or polyethylene or a polyurethane-base liquid material is used. Their characteristics are shown in FIG. 22. In essence, a formed sheet material is easy in application work and compared with a liquid material, is also advantageous in total cost.

However, the use of the conventional foamed material 100 made of such a synthetic rubber or urethane-base material (whose expansion ratio ranges from 200 to 2,000 percent) in pillars, a roof header panel and the like is accompanied by the problem that no contribution is made to improvements in their structural strength and rigidity, because the objective of its use is to improve the noise insulation and the energy absorption characteristics.

Incidentally, a closed-section structure is often used in connecting members of a vehicle so that rigidification of a foamed material, if feasible, is expected to improve the rigidity of such connecting members and/or to achieve their integration. However, the conventional foamed material 100 does not have a rigidity-improving function because its primary objective is to improve noise insulation or energy absorption as described above.

With the foregoing problem in view, the present invention has as its object the provision of a heat-foamble filling reinforcement of such a light weight and low price as not available to date and also of a reinforced closed-section structural-member structure making use of the heat-foamable filling reinforcement.

Disclosure of the Invention

A heat-foamable filling reinforcement according to the present invention is characterized in that said heat-foamable filling reinforcement comprises at least an epoxy resin material, a synthetic rubber material and a thermoplastic resin material as components, and said epoxy resin material amounts to 30-45 wt.%, said synthetic rubber material amounts to 5-15 wt.% and said thermoplastic resin material amounts to 5-15 wt.%, with the total of the weight percentages of the individual components being in a range not exceeding 100 wt.%. Owing to these characteristic features, the heat-foamable filling reinforcement according to the present invention bring about substantial improvements in flexural rigidity and twisting rigidity and also an improvement in energy absorption characteristics.

Preferably, the heat-foamable filling reinforcement further comprises a filler as a component, and the filler amounts to 40-50 wt.% with the total of the weight percentages of the individual components including the filler being in a range not exceeding 100 wt.%. These features can reduce the cost.

Further, a reinforced closed-section structural-member structure according to the present invention, said structure making use of a heat-foamable filling reinforcement and being formed of plural closed-section structural members connected together, is characterized in that the closed-section structural members are internally filled with a heat-foamable filling reinforcement which comprises an epoxy resin material, a synthetic rubber material and a thermoplastic resin material as components. These features can bring about improved rigidity, thereby making it possible to achieve a weight reduction through a reduction in the thickness of panels and also to attain obviation of reinforcing components such as a bulkhead. As a result, it is possible to meritoriously achieve a weight reduction as much as several kilograms per vehicle while sufficiently maintaining the noise insulation at the conventional level.

In the above-described structure, the heat-foamable filling reinforcement may also contain a filler as a component or calcium carbonate as a component. This feature makes it possible to prevent runs (sags) of the heat-foamable filling reinforcement upon heat-ing.

The heat-foamable filling reinforcement, which comprises the epoxy resin material, the synthetic rubber material and the thermoplastic resin material as the components, may be partially filled in or adjacent to connected parts of the closed-section structural members. This feature can contribute to a further improvement in rigidity and also to a further reduction in weight over the conventional heat-foamable filling reinforcements.

Further, the epoxy resin material amounts to 30-45 wt.% and is in the form of a foamed material, the synthetic rubber material amounts to 5-15 wt.%, and the thermoplastic resin material amounts to 5-15 wt.%. According to this composition, the content of the synthetic rubber material is as low as about 1/2 of the conventional content, whereby a plasticizer is no longer needed and a high expansion ratio and high rigidity can be achieved.

For the heat-foamed filling reinforcement, it is preferred to use a foamable material whose expansion ratio ranges from 200 to 500 percent after heating and cur-

ing. This makes it possible to fill the heat-foamable filling reinforcement at a higher efficiency in the closed-section structural members.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows sites to which the present invention is applied;
FIG. 2 shows a site to which the present invention is applied;
FIG. 3 illustrates working steps of an foamable material in the form of a sheet;
FIG. 4 illustrates use of a pre-formed reinforcement according to the present invention;
FIG. 5 depicts expansion ratios as a function of baking, foaming and curing conditions;
FIG. 6 depicts an appropriate range of baking, foaming and curing conditions;
FIG. 7(a) and FIG. 7(b) both illustrate the manner of handling of a clip insertion hole;
FIG. 8 illustrates use of straight frame specimens;
FIG. 9 shows the results of a flexural rigidity test;
FIG. 10 shows load-displacement characteristics in a compression test;
FIG. 11 depicts the specification of a specimen and test conditions;
FIG. 12 depicts rigidities measured on real components;
FIG. 13 illustrates the results of a static loading test of a center pillar;
FIG. 14 illustrates the results of a noise insulation test;
FIG. 15 shows components of a heat-foamable filling reinforcement according to the present invention and objectives of their addition;
FIG. 16 shows variations in principal physical properties depending on the composition;
FIG. 17 also shows variations in principal physical properties depending on the composition;
FIG. 18 also shows variations in principal physical properties depending on the composition;
FIG. 19 compares a heat-foamable filling reinforcement according to the present invention in physical properties with a foamed material of the prior art;
FIG. 20 compares the heat-foamable filling reinforcement according to the present invention in work characteristics with the the foamed material of the prior art;
FIG. 21 shows sites to which a conventional product is applied; and
FIG. 22 shows characteristics of formed sheets materials of a synthetic rubber, such as BR rubber or SBR rubber, or of polyethylene and a polyurethane-base liquid material, all, as conventional foamable materials.

BEST MODE FOR CARRYING OUT THE INVENTION

With reference to the drawings, a description will hereinafter be made about a heat-foamable filling reinforcement according to one embodiment of the present invention and a reinforced closed-section structural-member structure making use of the heat-foamable filling reinforcement.

First, characteristics and physical properties of the heat-foamable filling reinforcement according to the present invention will be described.

Upon development of the heat-foamable filling reinforcement (which may hereinafter be called "the developed material"), an investigation was conducted with a target placed in obtaining one permitting similar handling as foamable materials employed to date and as a light-weight and low-cost material, enabling to achieve an overall cost merit, to say nothing of a reduction in the weight of a real car. Although epoxy resins, polyurethanes, acrylic resins and the like were studied, a principal component of the material was limited to epoxy resins for their highest possibility of most closely approaching the above target.

On the premise that the heat-foamable filing reinforcement would be used in a weld assembling step (see the steps in FIG. 3) of a vehicle component, a formed sheet was chosen as the form of the material. According to the steps of FIG. 3, a component 20 is first pressed in a pressing step, a heat-foamable filling reinforcement 1 in the form of a sheet is bonded on the pressed component 21, and the pressed components 21,22 are welded together. The thus-welded components are then processed through a degreasing and washing step, and an electrodeposition step and foaming is completed in a baking step.

The heat-foamable filling reinforcement 1 in the form of the sheet is bonded on the pressed component 21 as described above. With a view to achieving improvements in initial adhesion and rustproofing properties, the heat-foamable filling reinforcement 1 was furnished as a double layer type which was composed of a pre-formed reinforcement a, and an adhesive layer b. Incidentally, in FIG. 4, c designates a release paper.

A description will next be made of features devised in composition, which have realized the high expansion ratio and high rigidity as great merits of the heat-foamable filling reinforcement 1.

The viscosity of an epoxy resin is readily affected by the temperature. In a high temperature range (160-200°C) as in a vehicle paint baking oven, the resin viscosity becomes excessively low so that the resin cannot hold decomposition gas of a foaming agent and can hardly achieve a high expansion ratio. With such a pr blem in background, a great deal of a synthetic rubber (BR, SBR or the like) has been incorporated to hold gas and a plasticizer has also been added to enhance the compatibility of the synthetic rubber. It has hence been difficult to obtain a high-rigidity body of a high expansion ratio from such a composition.

However, in attempts to increase the melt viscosity of a material and hence to improve the gas-holding ability at the time of baking and curing, attention was paid to

improve the compatibility between an epoxy resin and a synthetic rubber without adding a plasticizer. Thus, using as a base an epoxy resin on which a synthetic rubber had already been polymerized, a rubber of the same type was incorporated as a post additive, followed by further incorporation of a resin-base elastomer (thermoplastic resin material). Namely, the heat-foamable filling reinforcement 1 comprises at least an epoxy resin material, a synthetic rubber material and a thermoplastic resin material as components, and more specifically, it comprises 30-45 wt.% of the epoxy resin material, 5-15 wt.% of the synthetic rubber material, 5-15 wt.% of the thermoplastic resin material and further, 40-50 wt.% of a filler. As the heat-foamable filling reinforcement 1, an foamable material capable of achieving an expansion ratio of 200-500 percent after hearing and curing can be used. Further, one capable of providing compression strength as high as 10 kg/cm^2 or more can be used.

Here, the components of the heat-foamable filling reinforcement 1 and objectives of their addition are shown in FIG. 15.

As will also appreciated from FIG. 15, the epoxy resin material is added to impart high rigidity, high durability and high adhesion, the synthetic rubber material is added to impart formability, and the thermoplastic resin material is added to regulate the melt viscosity. Further, the foaming agent is added to achieve expansion or foaming, the curing agent and the curing accelerator are added to crosslink the epoxy resin material, carbon black is added to achieve reinforcement and coloring, and the filler is added to impart shape retention.

On the other hand, the proportions of the epoxy resin material, the synthetic rubber material, the thermoplastic resin material and the like are determined as will be described next.

First, concerning the epoxy resin material, its low proportion leads to inferior rigidity, durability and adhesion. At least 25 wt.% is therefore needed. Its high proportion, on the other hand, leads to a problem in cost, so that the upper limit is set at 40 wt.% or so.

With respect to the synthetic rubber material, its low proportion poses a problem in formability so that at least 5 wt.% is needed. Its high proportion, on the other hand, leads to a higher hardness, so that the upper limit is set at 15 wt.% or so.

Regarding the thermoplastic resin material, its proportion is set in a range of 5-15 wt.% from the viewpoint of regulation of the melt viscosity.

The synthetic rubber and the thermoplastic resin, which are essential elements of the present invention, will next be described further.

A description will first be made of the synthetic rubber.

Despite the form of the epoxy resin at room temperature (liquid to solid), it takes the form of a liquid having a low viscosity at high temperatures of 160-250°C so that it cannot hold decomposition gas of the foaming agent, thereby making it impossible to obtain a product of a high expansion ratio. Further, if the viscosity undergoes considerable variations depending on the temperature at the time of processing, inconvenience arises in compatibility upon mixing, in extrudability upon forming, etc.

To overcome these problems, the present invention makes use of the synthetic rubber which has good compatibility with the epoxy resin. Usable examples of the synthetic rubber include NBR, carboxylated NBR, epoxy NR, epichlorohydrin rubber, modified NBR, and the like.

When such a rubber is blended with the epoxy resin, viscosity is produced at a high-temperature time, thereby promoting the growth of films by foaming, enhancing the holding of foaming gas and hence making it possible to obtain a body of a high-expansion ratio.

In addition, the temperature-dependent viscosity variations are reduced, thereby improving the processability. Owing to the combination of this fact and the improved viscosity at room temperature, good bonding on a pressed component is always assured irrespective of the season.

To bring about these advantageous effects, the synthetic rubber is added in a proportion of 5-15 wt.% as described above. To achieve optimal expansion or foaming, however, 5-10 wt.% is desired. Incidentally, addition in a large proportion leads to a loss in reinforcing ability.

A description will next be made about the thermoplastic resin.

Namely, the thermoplastic resin is used to prevent runs (sags) under heat in an ED drying oven when the heat-foamable filling reinforcement (developed material) 1 is used in a vertical portion. Usable examples of the thermoplastic resin include polyvinyl butyral, styrene, modified styrene products, acrylic acid, modified acrylic products, polyamides and the like. Organic bentonite, colloidal silica or the like has conventionally be used. Use of these conventional materials results in a low viscosity and easy escape of at a high-temperature time, thereby failing to obtain a product of a high expansion ratio.

To overcome these problems, the present invention makes use of the thermoplastic resin so that at high temperatures, viscosity can be produced to such a level as eliminating runs or sags.

For this viscosity adjustment, the thermoplastic resin is generally added in a proportion of 5-15 wt.% although the proportion varies depending on the molecular weight and melting point of the resin. The optimal proportion ranges from 5 to 10 wt.%. An unduly large proportion leads to deteriorations in reinforcing ability and the fixedness on a greased surface.

Fibers (glass, pulp, or asbestos) or fine particulate calcium carbonate is used for the prevention of runs.

Since the content of the synthetic rubber in the heat-foamable filling reinforcement 1 has been reduced to about 1/2 of the conventional content as described above, a plasticizer has become no long r necessary so that a high expansion ratio and high rigidity have

been achieved.

Som examples will next be described together with comparative examples. They can be summarized as shown in FIG. 16 to FIG. 18.

In these figures, Comparative Example 1 employed, as a synthetic rubber material, SBR-1502 which does not have compatibility. The material therefore did not develop viscosity, had high fixedness on a greased surface, was putty and was not foamed. Comparative Example 2 employed organic bentonite for the prevention of sags, which adversely affected the foaming. In Comparative Example 3, the content of the synthetic rubber was increased so that the viscosity at high temperatures became higher, the expansion ratio was low, the resulting sheet was hard and the adhesion was lowered. In Comparative Example 4, the content of the thermoplastic resin material was increased so that like Comparative Example 3, the expansion ratio was lowered, the resulting sheet was hard and the adhesion was lowered. In Comparative Example 5, the content of the thermoplastic resin material was lowered, resulting in greater sags. In Comparative Example 6, the content of the synthetic rubber was lowered so that the expansion ratio became lower and the resulting sheet was not satisfactory in properties.

Incidentally, the term "developed material" as used in FIG. 18 means the heat-foamable filling reinforcement 1.

This developed material has also been found to achieve prevention of sags upon foaming and curing and also a uniform expansion ratio owing to its adjusted melt viscosity (see FIG. 5).

As a further characteristic feature, it is also mentioned that in addition to a high expansion ratio, the content of the filler (calcium carbonate or the like) has been increased close to 50% (by weight) based on the whole material to provide the material as an economical material.

Further, the developed material (the heat-foamable filing reinforcement according to the present invention) 1 is compared in physical properties with a foamed material of the prior art in FIG. 19.

A description will next be made about work characteristics of the developed material (the heat-foamable filing reinforcement according to the present invention) 1.

First, the developed material is used in a weld assembling step of a component (see FIG. 3) so that it is necessary to confirm its compatibility with working steps such as its greased surface adhesion, its vertical baking applicability and its influence to a painting step. Its foaming and curing properties are also important because electrodeposition coating formulations of low-temperature and short-time curing type are adopted recently and paint baking ovens have become lower in temperature and shorter in processing time.

It is however understood that the developed material 1 can meet a wide range of baking conditions from a low-temperature range to a high-temperature range owing to the adoption of a low-temperature reactive curing agent and a low-temperature decomposable foaming agent (see FIG. 6).

Further, front pillars and center pillars of a vehicle body, to which the heat-foamable filling reinforcement 1 according to the present invention is applied, are provided with many clip insertion holes for fixing trims, weather strip rubbers and the like. If the heat-foamable filling reinforcement 1 is applied as is, these holes are blocked and due to its high hardness, clips can no longer be inserted there. To avoid this problem, the heat-foamable filling reinforcement has a multi-layer sheet structure so that it is partly formed of a soft synthetic-rubber-base layer (soft layer of foamed material) 32 at a location corresponding to a clip insertion hole 31 as shown in FIG. 7(a). Owing to the provision of the soft layer of foamed material, a clip 33 can be easily inserted without lowering the rigidity of the resulting heat-foamed filing reinforcement as shown in FIG. 7(b). In FIG. 7(a) and FIG. 7(b), numeral 34 indicates an outboard pillar panel while numeral 35 designates an inboard pillar panel.

Other work characteristics are substantially the same as those of the current foamable material and involve no particular problems. The comparison results are shown in FIG. 20.

A further description will now be made about its application to a closed-section structural member.

First of all, quality confirmation making use of a straight frame will be described.

(1) Testing method

Used as a specimen was a specimen 41 which had been obtained by bonding a heat-foamable filling reinforcement (which may be called a "foamable material") on an inner wall of a hat-shaped frame, superposing an associated frame on the former frame, spot-welding the frames together, and then subjecting them to baking under predetermined conditions to cause foaming and curing of the formed sheet (see FIG. 8). Fixing plates are then welded to opposite ends of the specimen 41 to facilitate mounting of the specimen on a testing machine. Using such specimens, a bending test, a twisting test and a compression test were conducted.

(2) Test results

The frames with the foamable material 1 according to the present invention filled therein were improved in all the properties and exhibited flexural rigidity higher by as much as 15% (see FIG. 9) and twisting rigidity higher by as much as about 20%, both compared with the specimens without the foamable material. The filling of the foamable material 1 has therefore demonstrated to bring about sufficient advantageous effects.

Further, as is illustrated in FIG. 10, the average breaking resistance has also been found to increase by as much as about 50% in the compression test. In addi-

tion, with respect to the efficiency of energy absorption, better results were also obtained than those obtained from the specimen with the conventional foamable material.

Quality confirmation making use of a real component will next be described.

Using a connecting component between a roof rail and a center pillar of a vehicle, the possibility of a reduction in the thickness of a panel, a filling range of the foamable material and the rigidity were confirmed. Specifications of specimens and test conditions are shown in FIG. 11. The flexural rigidity and twisting rigidity were evaluated. As shown in FIG. 12, the results were expressed in terms of percent improvements over those of specimens of the current plate thickness which were not filled with any foamed material.

Described specifically, the thickness-reduced specimens were improved by as much as 3.0 times in twisting rigidity and by as much as 3.7 times in flexural rigidity (forward direction). In particular, the flexural rigidity in the inboard direction was improved by as much as about 8 times. Substantial advantages are therefore brought about by filling the foam. This can be considered to be attributable to effects of the thickness that the cross-sectional shape was convex in an outboard direction in both the roof rail and the center pillar. Further, the percent improvement of the rigidity of the partially-filled specimen was not substantially smaller than that of the full-surface filled specimen, thereby demonstrating a small contribution of the filling range of the foamable material. This indicates that a partially-filled component can exhibit sufficient effects. Accordingly, partial filling results in smaller increases in cost and weight and is considered to be an advantageous condition for practical adoption.

A further description will now be made about quality confirmation on real vehicles.

By applying the heat-foamable filling reinforcements 1 according to the present invention to various sites of the vehicle 10 constructed by connecting plural closed-section structural members such as the pillars 11-13, roof rails 14 and side sills 15 as illustrated in FIG. 1 and FIG. 2, a variety of confirmation tests were conducted to determine optimal effects. Specifically, the heat-foamable filling reinforcements 1 were applied in the connecting portion between the center pillar 12 and the roof rail 14 and also in the front pillar 11. Namely, in a vehicle structure constructed by connecting the plural closed-section structural members 11-15, the heat-foamable filling reinforcements 1 which contains the epoxy resin material, the synthetic rubber material and the thermoplastic resin material as components are filled partially in the connecting portion between the closed-section structural members and also adjacent to the connecting portion, specifically, in a portion adjacent to the connecting portion, for example, within 300 mm from the connecting portion, respectively.

A rigidity test was conducted while applying a load to a point A at a right angle in an inboard direction in FIG. 1. A noise insulation test was conducted by measuring a noise level at a point B by a microphone in FIG. 2.

First, as a result of an inboard, static load bending test of the center pillar 12, a rigidity improvement by as much as about 14% was observed over the center pillar not filled with the foamable material. A rise in load on a load-displacement curve was steep, that is, the displacement at the time of the peal load was as much as about 7 mm, thereby demonstrating that the foamable material is also expected to bring about an improvement in energy absorption (see FIG. 13).

Concerning the noise insulation, on the other hand, the internal noise of the front pillar during 100 km/hr running was reduced by 7 to 8 dB on average in a frequency range of 250 Hz and higher, thereby demonstrating sufficient effects (see FIG. 14).

Incidentally, those which were referred to above with numeral 1 in the above Examples (the foamable materials, developed materials and the like) all indicate heat-foamable or heat-foamed filling reinforcements according to the present invention.

Accordingly, the following matters can be mentioned.

In each Example, the rigidity of the closed-section structure was successfully improved owing to the use of the heat-foamable filling reinforcement 1. This makes it possible to achieve a weight reduction through a reduction in the thickness of the panel and also to obviate a reinforcement part such as a bulk-head. As a consequence, the prescribed effect can be obtained (a weight reduction as much as several kilograms per vehicle) while sufficiently assuring the conventional noise insulation.

Needless to say, the heat-foamable filling reinforcement 1 which contains the epoxy resin material, the synthetic rubber material and the thermoplastic resin material as components can be filled over a substantial portion (including the whole portion) of the interior of each closed-section structural member such as a pillar.

CAPABILITY OF EXPLOITATION IN INDUSTRY

According to the present invention, substantial improvements can be achieved in flexural rigidity and twisting rigidity and also improvements in energy absorption characteristics. This invention is therefore suited for use in reinforced closed-section structural-member structures of a vehicle such as an automobile.

Claims

1. A heat-foamable filling reinforcement characterized in that said heat-foamable filling reinforcement comprises at least an epoxy resin material, a synthetic rubber material and a thermoplastic resin material as components, and said epoxy resin material amounts to 30-45 wt.%, said synthetic rubber material amounts to 5-15 wt.% and said ther-

moplastic resin material amounts to 5-15 wt.%, with the total of the weight percentages of the individual components being in a range not exceeding 100 wt.%.

2. A heat-foamable filling reinforcement according to claim 1, wherein said heat-foamable filling reinforcement (1) comprises a filler as a component, and said filler amounts to 40-50 wt.% with the total of the weight percentages of the individual components including said filler being in a range not exceeding 100 wt.%.

3. A reinforced closed-section structural-member structure making use of a heat-foamable filling reinforcement and formed of plural closed-section structural members (11-15) connected together, characterized in that said closed-section structural members (11-15) are internally filled with a heat-foamed filling reinforcement (1) which comprises an epoxy resin material, a synthetic rubber material and a thermoplastic resin material as components.

4. A reinforced closed-section structural-member structure according to claim 3, wherein said heat-foamed filling reinforcement (1) comprises a filler as a component.

5. A reinforced closed-section structural-member structure according to claim 4, wherein said heat-foamed filling reinforcement (1) comprises calcium carbonate as a component.

6. A reinforced closed-section structural-member structure according to claim 3, wherein said heat-foamed filling reinforcement (1), which comprises said epoxy resin material, said synthetic rubber material and said thermoplastic resin material as said components, is partially filled in or adjacent to connected parts of said closed-section structural members (11-15).

7. A reinforced closed-section structural-member structure according to claim 3, wherein said epoxy resin material amounts to 30-45 wt.% and is in the form of a foamed material, said synthetic rubber material amounts to 5-15 wt.%, and said thermoplastic resin material amounts to 5-15 wt.%.

8. A reinforced closed-section structural-member structure according to claim 6, wherein said epoxy resin material amounts to 30-45 wt.% and is in the form of a foamed material, said synthetic rubber material amounts to 5-15 wt.%, and said thermoplastic resin material amounts to 5-15 wt.%.

9. A reinforced closed-section structural-member structure according to any one of claims 3, 6, 7 and 8, wherein said heat-foamed filling reinforcement (1) has been formed using a foamable material whose expansion ratio ranges from 200 to 500 percent after heating and curing.

FIG. 1

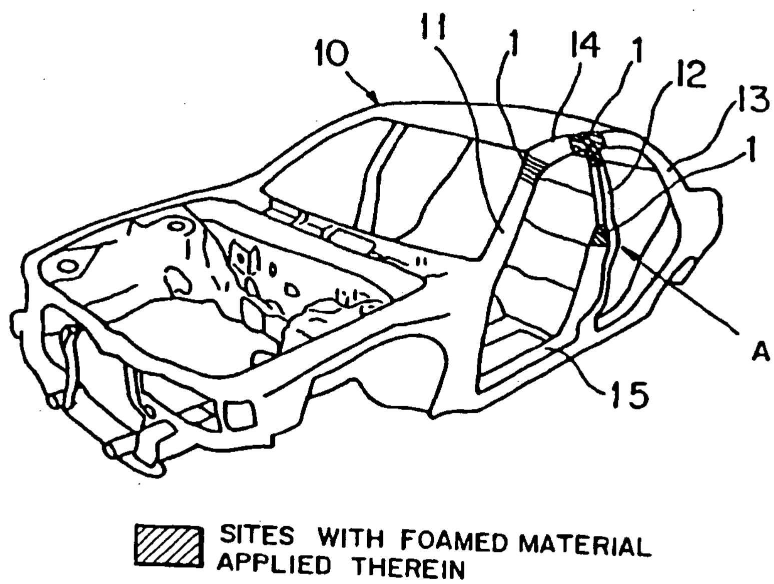

10
11
1
14
1
12
13
1
A
15
SITES WITH FOAMED MATERIAL
APPLIED THEREIN

FIG. 2

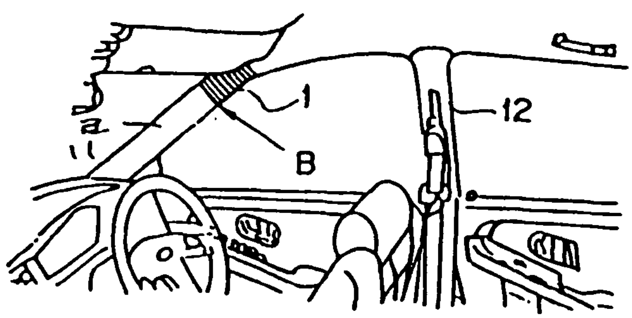


FIG. 3

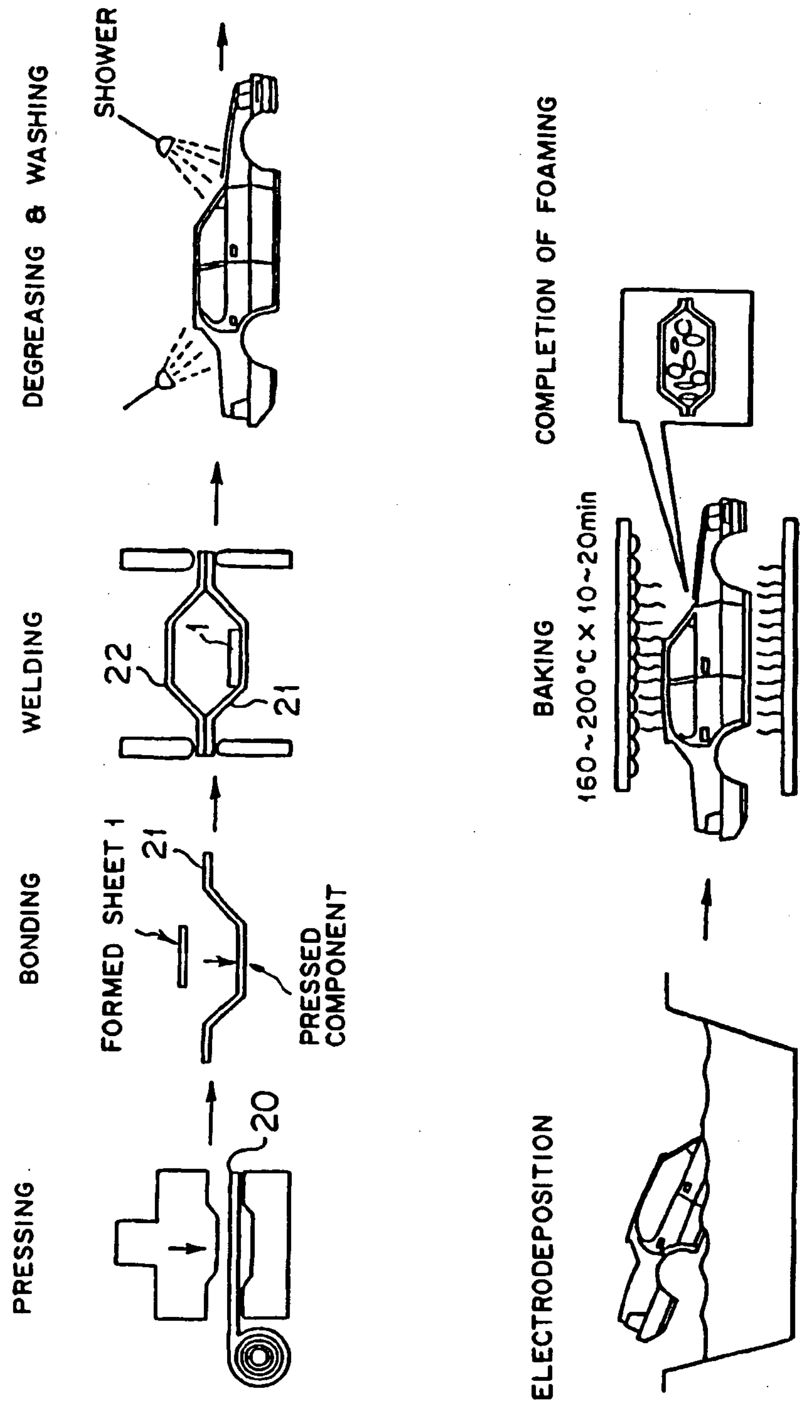

PRESSING
BONDING
WELDING
DEGREASING & WASHING
SHOWER
FORMED SHEET 1
PRESSED COMPONENT
20
21
22
1
21
ELECTRODEPOSITION
BAKING
160~200°C X 10~20min
COMPLETION OF FOAMING

FIG. 4

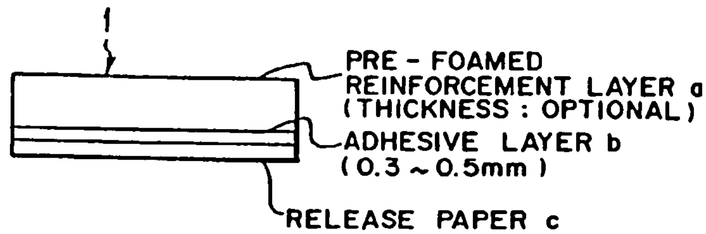
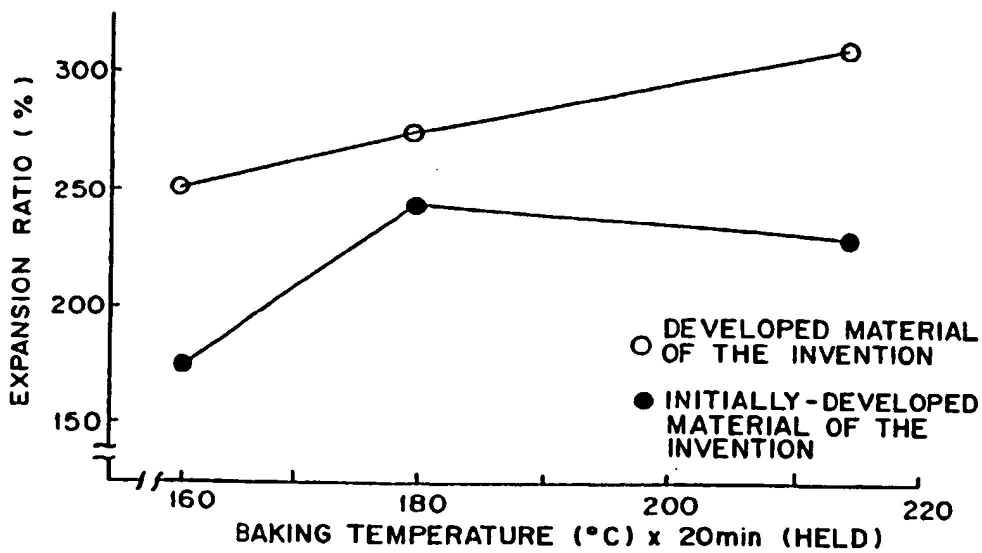

1
PRE - FOAMED
REINFORCEMENT LAYER a
(THICKNESS : OPTIONAL)
ADHESIVE LAYER b
(0.3 ~ 0.5mm)
RELEASE PAPER c

FIG. 5


EXPANSION RATIO (%)
300
250
200
150
160
180
200
220
BAKING TEMPERATURE (°C) x 20min (HELD)
○ DEVELOPED MATERIAL OF THE INVENTION
● INITIALLY-DEVELOPED MATERIAL OF THE INVENTION

F I G. 6

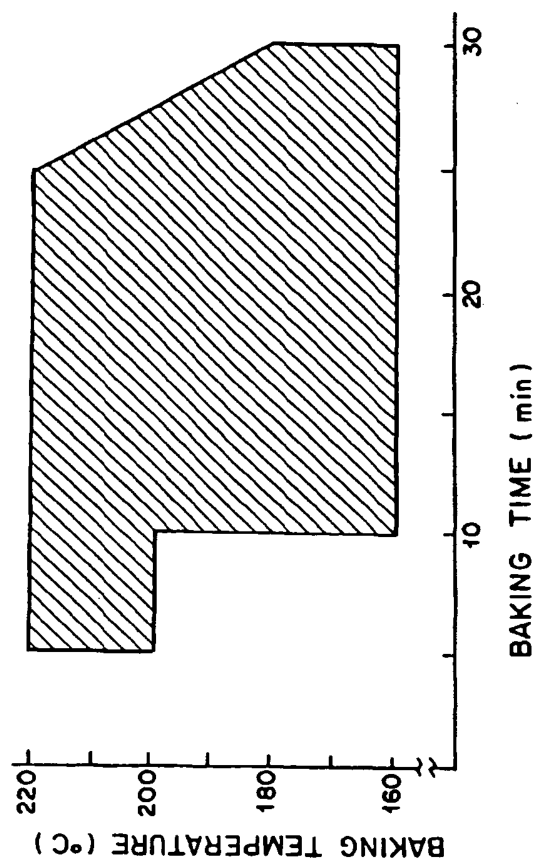


FIG. 7(a)

BEFORE FOAMING AND CURING

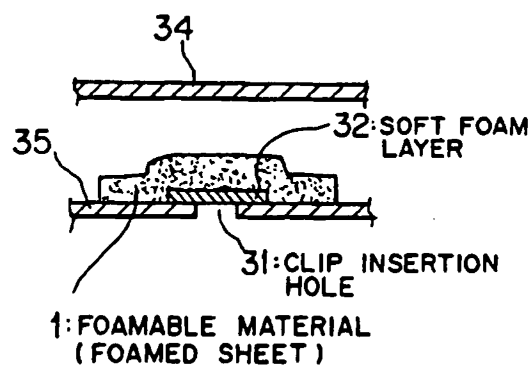


FIG. 7(b)

AFTER FOAMING AND CURING

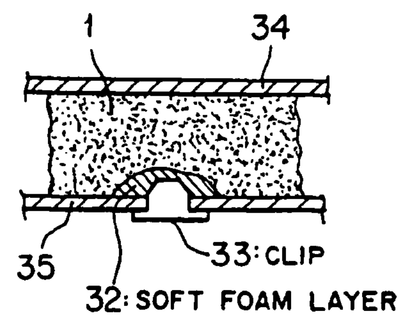


FIG. 8

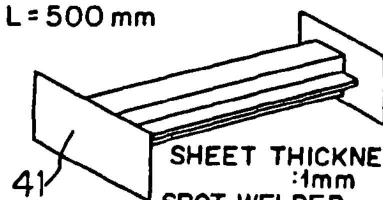
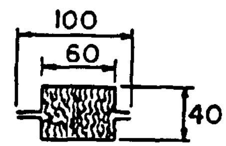
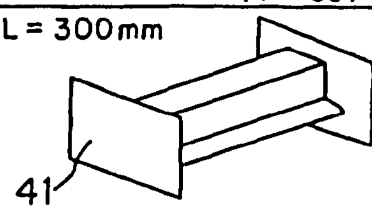
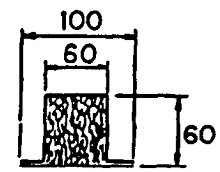
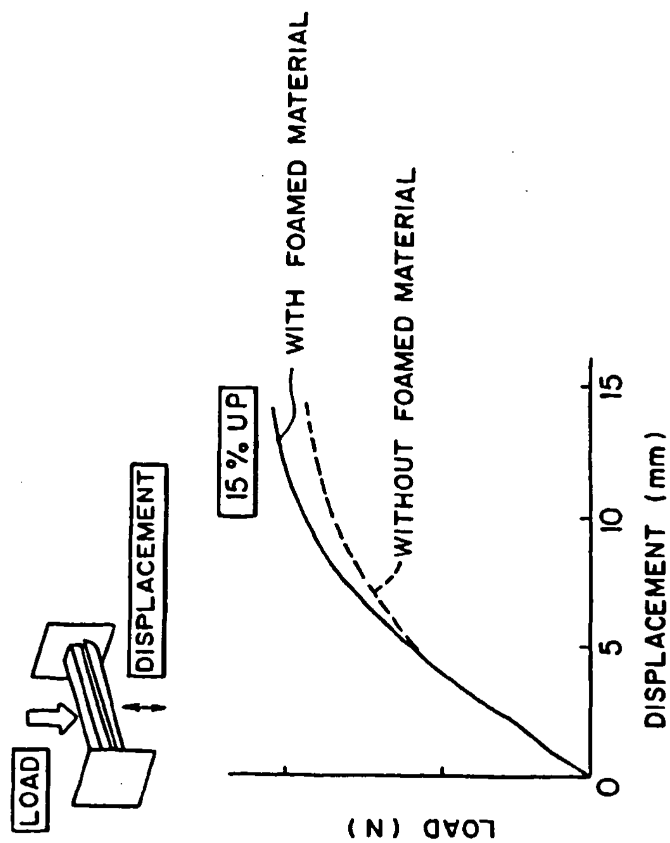
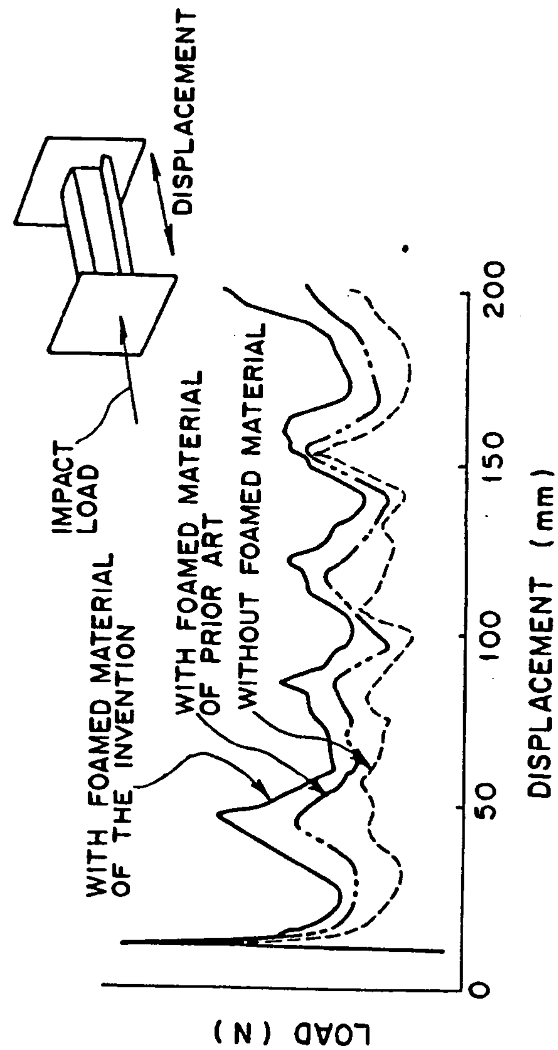
	SHAPE	CROSS-SECTION
FOR FLEXURAL OR TWISTING TEST	L = 500 mm  SHEET THICKNESS :1mm SPOT WELDED (P = 50)	
FOR COMPRESSION TEST	L = 300 mm  SHEET THICKNESS: 1mm SPOT WELDED (P = 50)	

FIG. 9


LOAD
DISPLACEMENT
15% UP
WITH FOAMED MATERIAL
WITHOUT FOAMED MATERIAL
LOAD (N)
DISPLACEMENT (mm)
0
5
10
15

F I G. 10


DISPLACEMENT
IMPACT LOAD
WITH FOAMED MATERIAL OF THE INVENTION
WITH FOAMED MATERIAL OF PRIOR ART
WITHOUT FOAMED MATERIAL
0
50
100
150
200
DISPLACEMENT (mm)
LOAD (N)

F I G. 11

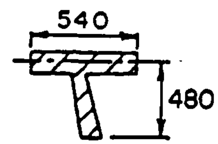
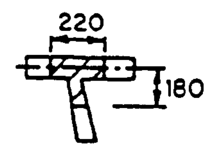
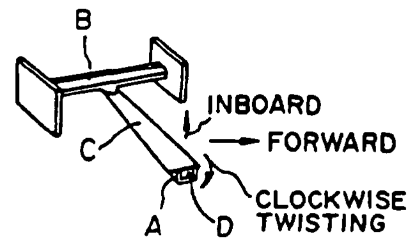
FILLING RANGE OF FOAMED MATERIAL	FULL - FACE FILLING		PARTIAL FILLING	TEST CONDITIONS
				
PANEL THICKNESS (mm)	PANEL	CURRENT PRODUCT	PRODUCTS WITH REDUCED SHEET THICKNESS	
	A	0.70	0.65	
	B	1.00	0.90	
	C	1.20	1.00	
	D	1.00	0.90	

FIG. 12

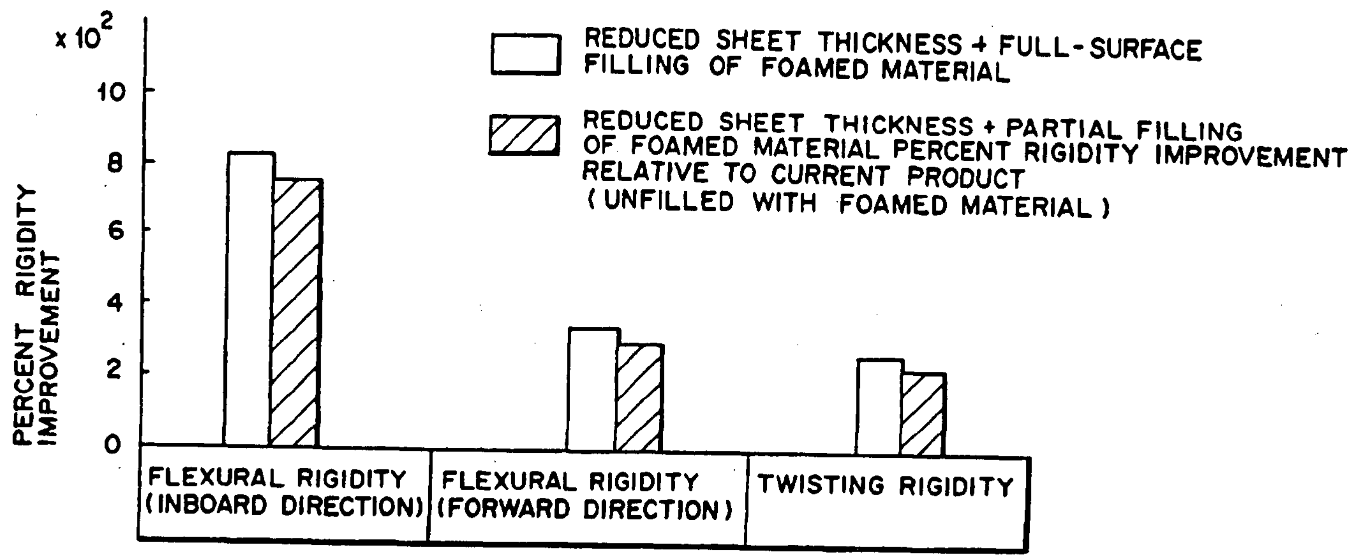

x 10^2
10
8
6
4
2
0
PERCENT RIGIDITY IMPROVEMENT
REDUCED SHEET THICKNESS + FULL-SURFACE FILLING OF FOAMED MATERIAL
REDUCED SHEET THICKNESS + PARTIAL FILLING OF FOAMED MATERIAL PERCENT RIGIDITY IMPROVEMENT RELATIVE TO CURRENT PRODUCT (UNFILLED WITH FOAMED MATERIAL)
FLEXURAL RIGIDITY (INBOARD DIRECTION)
FLEXURAL RIGIDITY (FORWARD DIRECTION)
TWISTING RIGIDITY

FIG. 13

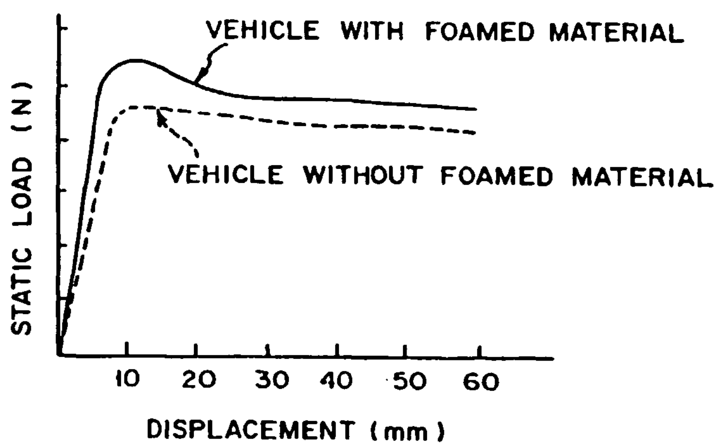
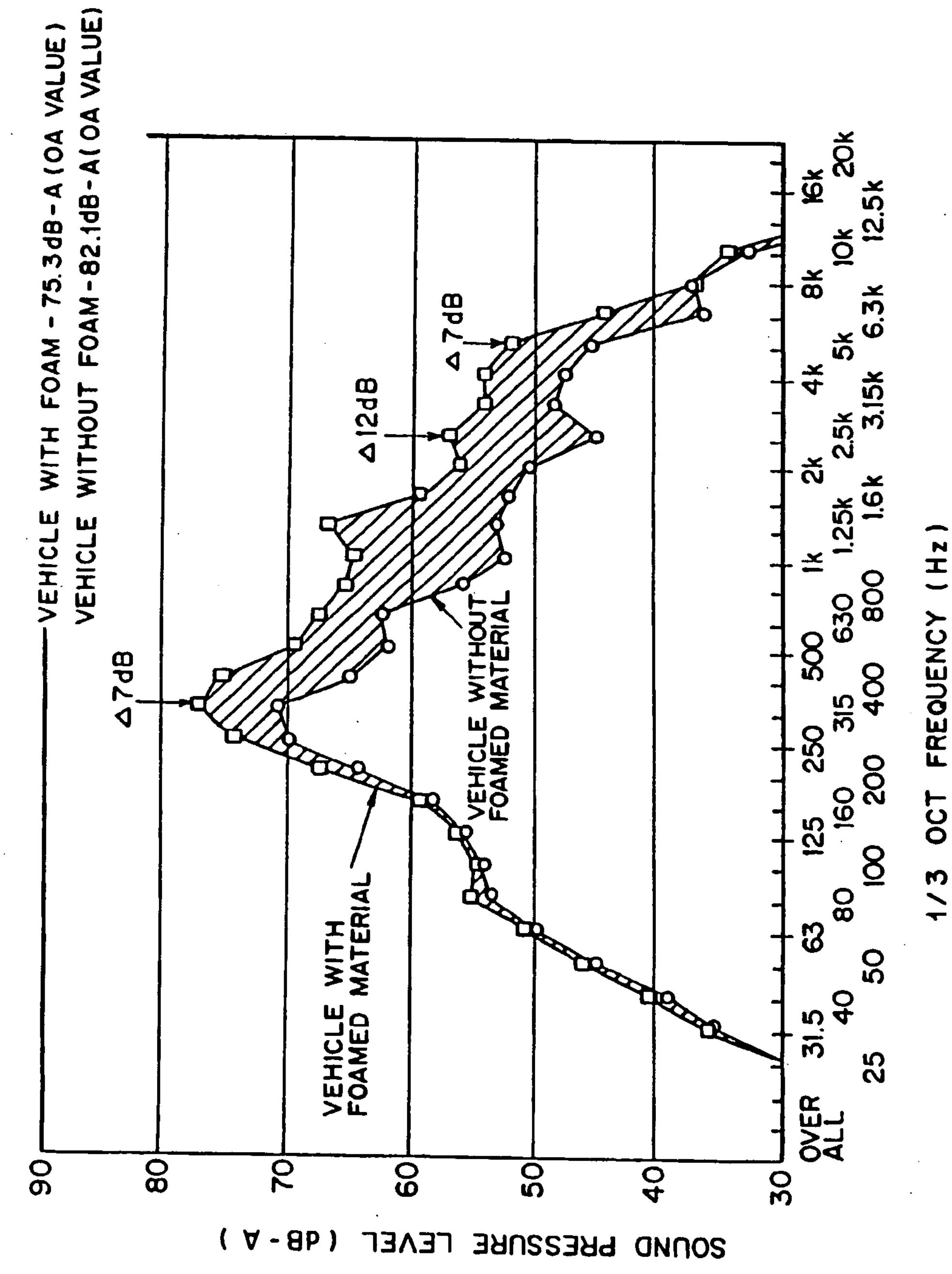

VEHICLE WITH FOAMED MATERIAL
VEHICLE WITHOUT FOAMED MATERIAL
STATIC LOAD (N)
10 20 30 40 50 60
DISPLACEMENT (mm)

FIG. 14



VEHICLE WITH FOAM - 75.3dB-A (OA VALUE)
VEHICLE WITHOUT FOAM - 82.1dB-A (OA VALUE)
Δ7dB
Δ12dB
Δ7dB
VEHICLE WITH FOAMED MATERIAL
VEHICLE WITHOUT FOAMED MATERIAL
SOUND PRESSURE LEVEL (dB-A)
90
80
70
60
50
40
30
OVER ALL
25
31.5
40
50
63
80
100
125
160
200
250
315
400
500
630
800
1k
1.25k
1.6k
2k
2.5k
3.15k
4k
5k
6.3k
8k
10k
12.5k
16k
20k
1/3 OCT FREQUENCY (Hz)

FIG. 15

Components of Developed Material
and Objectives of Their Addition

Material	Weight percentage (wt.%)	Objective of addition
Epoxy resin	35	High rigidity, high durability, high adhesion
Synthetic rubber	8	Formability
Thermoplastic elastomer	6	Adjustment of melt viscosity
Foaming agent	2	Foaming
Curing agent, curing accelerator	3	Crosslinking of epoxy resin
Carbon black	2	Reinforcement Coloring
Filler	44	Shape retention
Total	100	

FIG. 16

Compositions and Principal Physical Properties

	Ex. 1	Ex. 2	Comp. Ex. 1	Comp. Ex. 2
Epoxy resin (wt.%)	35	35	35	35
Modified NBR (wt.%)	8	10	–	8
SBR-1502 (wt.%)	–	–	8	–
Modified styrene (wt.%)	7	6	7	–
Organic bentonite (wt.%)	–	–	–	7
Foaming agent (wt.%)	2	2	2	2
Curing agent (wt.%)	3	3	3	3
Calcium carbonate (wt.%)	45	44	45	45
Expansion ratio (%)	350	330	100	150
Sags (mm)	15	15	15	20
Greased surface adhesion	A	A	C	A

A: good, C: unacceptably poor.

FIG. 17

Compositions and Principal Physical Properties

	Comp. Ex. 3	Comp. Ex. 4	Comp. Ex. 5	Comp. Ex. 6
Epoxy resin (wt.%)	35	35	35	35
Modified NBR (wt.%)	25	8	8	2
SBR-1502 (wt.%)	-	-	-	-
Modified styrene (wt.%)	7	20	2	7
Organic bentonite (wt.%)	-	-	-	-
Foaming agent (wt.%)	2	2	2	2
Curing agent (wt.%)	3	3	3	3
Calcium carbonate (wt.%)	25	32	50	50
Expansion ratio (%)	200	270	360	250
Sags (mm)	25	10	65	25
Greased surface adhesion	B	C	A	A

A: good, B: somewhat inferior, C: unacceptably poor.

FIG. 18

Compositions and Principal Physical Properties

	Components & Physical properties \ Materials	Developed Material	Comp. Material	Comp. Material
Composition, %	Rubber-modified epoxy resin	35	30	35
	Plasticizer	0	3	5
	High-compatibility rubber	8	-	-
	General-purpose synthetic rubber	-	16	15
	Thermoplastic elastomer	7	7	2
	Filler	45	40	35
	Others	5	4	8
PPP*	Expansion ratio (%)	280	100	250
	Modulus of flexural elasticity (Mpa)	550	100	80
	Saggs (mm)	15	15	60

* PPP: Principal Physical Properties

FIG. 19

Principal Physical Properties of Developed Material

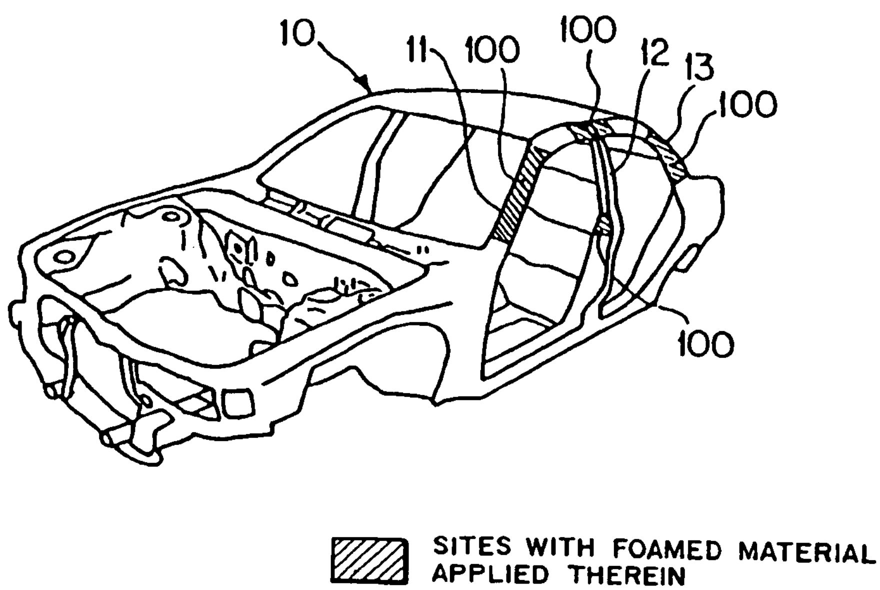
Tested properties			Results: Developed Material	Results: Current expandable filling material
Before curing	Specific gravity 20°C	Before baking	1.21	1.10
		After baking	0.40	0.13
	Ash content %	180° x 20 min	22.8	16.1
Physical properties after curing	Water absorption %	20°C H_2O x 24 hr	3.0	5.7
	Post-water-absorption restorability %	20°C H_2O x 48 hr	2.7	1.3
	Flexural strength MPa	Under 20°C atmosphere	1.7	-
	Compression strength MPa	Under 20°C atmosphere	1.3	-
Physical properties of adhesion	Adhesive strength MPa	Under 20°C atmosphere	2.7	0.03
	Impact resistance (times)	20° x 3 hr	3	
		After 80° x 336 hr	6	
		After 50°, 95% x 336 hr	13	
		After 5 heat cycles	6	
		After 40°C H_2O x 336 hr	20	
	Corrosion resistance	After 48 dry/wet cycles	No rusting	No rusting

FIG. 20

Principal Work Characteristics

Tested characteristics		Requirements	Developed material	Foamed material of prior art
Welding step	Fixedness on greased surface	Should be free from separation, displacement or falling	No problem	No problem
	Storage stability	≥150%	200-300	700-750
Coating step	Fouling tendency of degreasing solution	Should be free from fouling of solution or dissolution of sheet	No problem	No problem
	Fouling tendency of chemical solution		No problem	No problem
	Fouling tendency of electrodeposition soln.		No problem	No problem
	Vertical baking applicability	Should be free from sagging or sagged tearing	No problem	No problem
	Expandability	≥200	250-300	800-900
	Odoriferousness	Should be free of unpleasant or irritating odor	No problem	No problem

F I G. 21


10
11
100
100
12
13
100
100
SITES WITH FOAMED MATERIAL APPLIED THEREIN

F I G. 22

Types of Foamable Filling Materials and Their Characteristics

	Formed sheet material		Liquid material
	BR rubber base	Polyethylene base	Polyurethane base
Application step	Weld assembling step	Weld assembling step	Installation and assembling step
Application method	Bonding of extruded sheet	Mechanical fastening of injection-modlded sheet	Injection through 2-pack mixing nozzle
Curing method	Cured in ED coating baking oven	Cured in ED coating baking oven	Cured through room-temperature reaction
Greased surface adhesion	A	A	C
Prevention of liquid leakage	Not needed	Note needed	Needed (partitions or the like)
Rustproofing properties	A	B	C
Noise insulation	A	B	A
Flexural strength	C	B	B
Facilities	Not needed	Not needed	Mixing coating is needed
Total cost	A	A	B

A: good, B: somewhat inferior, C: unacceptably poor.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP96/00073

A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl^6 C08J9/06

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Int. Cl^6 C08J9/00-11/28

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1926 - 1996
Kokai Jitsuyo Shinan Koho	1971 - 1996

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	JP, 4-264142, A (Nippon Zeon Corp.), September 18, 1992 (18. 09. 92), Lines 2 to 16, left column, page 2, lines 7 to 24, left column, page 5, line 44, left column to line 4, right column, page 5	1 - 9
Y	JP, 56-127639, A (Nitto Denko Corp.), October 6, 1981 (06. 10. 81), Lines 5 to 11, left column, page 1, lines 5 to 11, lower right column, page 2	1 - 9

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
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"O" document referring to an oral disclosure, use, exhibition or other means
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"&" document member of the same patent family

Date of the actual completion of the international search April 1, 1996 (01. 04. 96)	Date of mailing of the international search report April 16, 1996 (16. 04. 96)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (July 1992)